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Research Article

Research on Comprehensive Evaluation of Heilongjiang Province's Modern Industrial System

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Abstract: Based on the principles of systematization, independence, comparability, and quantification, combined with the current state of Heilongjiang Province's modern industrial system and its own development characteristics, the index factors that represent the Heilongjiang Province's modern industrial system were selected from a number of indicators, and constructing 5 dimensions and 23 indicators. The index system of this region is evaluated by the improved entropy method and principal component analysis. The weight of each index of Heilongjiang's modern industrial system is obtained by improving the entropy method. Among them, the impact of ecological service is the largest, and the impact of opening to the outside world is the weakest, and the comprehensive score of Heilongjiang's modern industrial system is the highest in 2014; the principal component analysis method The 23 indicators of the modern industrial system of Heilongjiang Province can be transformed into three independent comprehensive indicators, all of which have a characteristic value of> 1 and a cumulative contribution rate of 90.725%, reflecting most of the information of the modern industrial system of Heilongjiang Province. This study has obtained the development status of the modern industrial system of Heilongjiang Province, and can make suggestions for further adjustment or focus on strengthening the modern industrial system of Heilongjiang Province.

Keywords: Modern industrial system; improved entropy method; principal component analysis method; comprehensive evaluation.

INTRODUCTION

In today's economic globalization, modern industrial system can promote national development, promote technological innovation of core industries, speed up the transition from traditional industries to new ones, and constantly improve the industrial structure. So scholars at home and abroad are constantly studying and exploring a suitable development model of modern industrial system. Rancois, Jospeh, Bernard Hoekman (2010) pointed out that many international experiences show that compared with manufacturing, service industry can promote economic growth, create jobs and reduce poverty more (Guerrieri, P., & Meliciani, V. 2004; Hoekman, B., & Mattoo, A. 2008; & Francois, J., & Hoekman, B. 2010). China's economy is changing from high-speed development to high-quality development stage, and the modern industrial system is its internal requirement. Therefore, various regions have begun to study the modern industrial system and seek the right way of high-quality economic development. In the process of seeking a new modern industrial system, the traditional industrial system cannot be ignored. Zhang Yaohui (2012) analyzed the operation characteristics, transformation process, nature and composition of the traditional industrial system, as well as the formation mechanism of the modern industrial system, and pointed out that China is suitable for the government promotion mechanism Zhang Jixin (2012) based on the three-dimensional model of coordination degree, agglomeration degree and competition degree of modern industrial system of urban agglomerations, constructed the evaluation index system of modern industrial system of urban agglomerations composed of 28 indexes, calculated the development index of modern industrial system of urban agglomerations, and provided the basis for the formation path of modern industrial system of urban agglomerations designed reasonably in combination with their own characteristics Yang Yiwen, Zheng Jianghuai, Huang Yongchun and Ren Zhicheng (2012) believed that the modern industrial system is an important sign of a region's economic development level and comprehensive strength, and we should accelerate the transformation from the manufacturing based industrial system to the service-oriented industrial system. Xie Hao and Zhang Mingzhi (2013)

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emphasized their characteristics in the study of the definition of modern industrial system, and believed that the core content of modern industrial system is the integration growth of advanced manufacturing industry and modern productive service, characterized by openness, innovation, agglomeration and integration. Xie Sixian and Dai Yalan (2016) proposed that the modern industrial system is the integration and development of industries, as well as the new carrier and new form of transforming the economic development mode and building a harmonious society Huang Haosen and Yang huigai (2018). comprehensively constructed the modern industrial system of relevant international competitiveness, and through the evaluation and research of 28 typical regions at home and abroad by principal component analysis, put forward the idea of improving the international competitiveness of regional modern industrial system based on the optimization of modern industrial structure by value chain and the enhancement of innovation ability by innovation chain Lu Huang Zijia and Lin Xiaojian (2019) believed that after the 19th National Congress of the Communist Party of China in 2017, the academic community turned its attention back to the development of modern industrial system. To maintain the economic competitive advantage, a modern industrial system with international competitiveness is the only way Li Qiaoxing and Xu Sihui (2019). Concluded that in the new normal stage of economic development, industrial transformation and upgrading will become a new research trend in the field of modern industrial system. With the continuous progress of the construction of China's modern economic system, research institutions and authors should strengthen cooperation and deepen the theoretical results of various research topics, so as to provide think tank support for the realization of China's development strategic goals.

The analysis and research on the modern industrial system of Heilongjiang province plays an important role in the comprehensive development of Heilongjiang Province, and even has a subtle influence on the whole northeast. First of all, through consulting the relevant literature to grasp the development direction of modern industrial system, understand the methods and models of comprehensive evaluation and analysis of modern industrial system, so that get the dimensions and relevant indicators, and through the statistical yearbook of Heilongjiang Province to find out the indicator data for sorting. Then, factor analysis and improved entropy method are used to analyze the data. At last, we get the current situation of modern industrial system in Heilongjiang Province, and put forward reasonable solutions and policy suggestions for the more prominent problems.

Construction of comprehensive evaluation index of Heilongjiang province's modern industrial system

Based on the above-mentioned principles of systematization, independence, comparability, and quantification, combined with the current state of Heilongjiang Province's modern industrial system and its own development characteristics, the index factors that are representative of Heilongjiang's modern industrial system were selected from a number of indicators, and five dimensions were constructed for regional competitiveness, openness , scientific and technological innovation, education and culture, and ecological services, 23 indicators were selected for the five dimensions to form a comprehensive indicator system for the modern industrial system of Heilongjiang Province. Show in Table 2-1.

Table 2-1 Evaluation index of Heilongjiang province's modern industrial system

Dimensions	Index
Regional competitiveness A1	B1--Total output value of primary industry
	B2--Total output value of secondary industry
	B3--Regional total output value per capita
	B4--Added value of tertiary industry
OpennessA2	B5--Total import and export of goods
	B6--Actual utilization of foreign capital
	B7--Loss making enterprises
Scientific and technological innovation A3	B8--Number of enterprises with R&D activities
	B9--Proportion of internal expenditure of R&D funds in main business income（%）
	B10--Number of R&D projects
	B11--Number of personnel in R&D organization of Enterprise Office
	B12--Number of three patents authorized
Educational culture A4	B13--All kinds of schools in the province（except for schools for the deaf and mute）
	B14--Number of teachers at all levels in the province(except for schools for the deaf and mute）
	B15--Number of college students per 10000
	B16--Number of graduate from graduate school
	B17--Number of cultural relics and institutions
	B18--Number of cultural relics practitioners in the province
Ecological service A5	B19--Having beds in health institutions per 10000 people

B20--Having health technical personnel per 10000 people
B21--Park green area per capita
B22--Green food industry certification area
B23--Forest coverage（%）

The profit and loss of an enterprise is related to all aspects of the construction of a province and the common development of enterprises is an important driving force for the economic development of a province. Heilongjiang Province, as a large province bordering Russia, not only has many excellent domestic sales enterprises, but also many new foreign trade enterprises, which impacts on some small enterprises. Therefore, in the first dimension, loss making enterprises are selected as an indicator of openness to the outside world. From the perspective of industry development, with the improvement of people's living standards and the change of consumption concept, pollution-free and safe green food has become a fashion, and more and more popular. In the future, no matter at home or abroad, green food has great development potential. Therefore, the certification area of green food industry is taken as the index of ecological service dimension.

DATA SOURCES AND PROCESSING METHODS

Data Sources and Processing

In the second chapter of this study, an index system for evaluating the modern industrial system of Heilongjiang Province was constructed. According to the quantifiable principle of data and the availability of data, the data used in this research are all digital indicators. The data of this study mainly comes from the《Heilongjiang Statistical Yearbook》 from the year 2006 to 2018(shown in Appendix 1). The index system of this study contains 23 indicators in 5 dimensions. Because the units of each evaluation index are different, the data needs to be standardized. Since there may be positive indicators and negative indicators in the indicator system, so that use normalization deal with.

Normalization of indicators: homogeneity of heterogeneous indicators. For n samples and m indicators, x_{ij} is the value of the j-th indicator of the i-th sample (i = 1, ..., n; j = 1, ..., m). Because the measurement units of the indicators are not uniform, they must be standardized before calculation. The processing results are shown in Appendix 2.

Establishment of Comprehensive Evaluation Model of Modern Industrial System in Heilongjiang Province
Evaluation of the modern industrial system of Heilongjiang Province based on the improved entropy method

Establishment of Improved Entropy Model

The steps of improving entropy method are as follows:

(1) For n samples and m indicators, xij is the value of the j-th indicator of the i-th sample (i = 1, ..., n; j = 1, ..., m). Becau se the measurement units of the indicators are not uniform, they must be standardized before calculation.

(2) According to the definition of entropy, the proportion of the i-th sample value in the j-th index is:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}, i = 1, \dots, n, j = 1, \dots, m$$

(3) Calculate the entropy value of index j-th:

$$e_j = -k \sum_{i=1}^{n} p_{ij}\, ln(p_{ij}), j = 1, \dots, m$$where, k =1/ln(n) >0, satisfying ej≥0;

(4) Calculate information entropy redundancy (difference):

$$d_j = 1 - e_j, j = 1, \dots, m$$ (5) Calculate the weight of each index:

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j}, j = 1, \dots, m$$(6) Calculate the comprehensive score of each

$$s_i = \sum_{j=1}^{m} w_j p_{ij}, i = 1, \dots, n$$

Determine the Weight of the Improved Entropy Method

On the basis of normalized data, we use the improved entropy method to determine the information entropy redundancy, weight and comprehensive score of 23 indicators, and respectively sum the weight of five dimensions of regional competitiveness, openness, technological innovation, education and culture, and

ecological service to get the weight of each dimension. According to the improved entropy method, we use Matlab to calculate, and the results are shown in table 3-1.

Table 3-1 specific calculation value of evaluation index of modern industrial system in Heilongjiang Province

Dimension classifications	Specific indicators	Information redundancy *D*	Index entropy weight *W*	Dimension classifications	Specific indicators	Information redundancy *D*	Index entropy weight *W*
Regional competitiveness A1	B1	0.8746	0.0576	Educational culture A4	B19	0.8688	0.0603
	B2	0.9189	0.0373		B20	0.8999	0.0460
	B3	0.9028	0.0447		B21	0.9201	0.0367
	B4	0.8762	0.0569		B22	0.9027	0.0447
	Subtotal	3.5725	0.1965		B23	0.8891	0.0510
Openness A2	B5	0.8936	0.0489		Subtotal	4.4986	0.2387
	B6	0.8832	0.0537	Ecological service A5	B19	0.8688	0.0603
	B7	0.9470	0.0243		B20	0.8999	0.0460
	Subtotal	2.7238	0.1269		B21	0.9201	0.0367
Scientific and technological innovation A3	B8	0.9125	0.0402		B22	0.9027	0.0447
	B9	0.9150	0.0390		B23	0.8891	0.0510
	B10	0.9237	0.0350		Subtotal	4.4986	0.2387
	B11	0.8889	0.0510				
	B12	0.8693	0.0600				
	Subtotal	4.5094	0.2252				
composite score S	2005	2.3185		2006	3.1046	2007	3.5586
	2008	5.1797		2009	5.6294	2010	7.4580
	2011	9.4806		2012	10.2682	2013	9.9629
	2014	11.1191		2015	10.5935	2016	10.6139
	2017	10.7129					

According to table 3-1, the information redundancy, index entropy weight and total comprehensive score of each index are calculated. It can be seen that the information redundancy is basically close to no big fluctuation, which shows that the data reliability is high.

The entropy weight of regional competitiveness, openness, technological innovation, education and culture, and ecological service is 0.1965, 0.1269, 0.2252, 0.2127 and 0.2387. It can be seen that the ecological service has a great impact on the modern industrial system of Heilongjiang Province. It shows that the modern industrial system of Heilongjiang Province has a strong correlation with the ecology and people's livelihood. The second biggest influence is technological innovation. Opening to the outside world has the weakest impact on the modern industrial system of Heilongjiang Province, which indicates that there are problems in the opening-up of the modern industrial system of Heilongjiang Province. From the comprehensive score from 2005 to 2017, it can be seen that the modern industrial system of Heilongjiang Province has developed rapidly. In 2014, the comprehensive score was 11.1191, with the highest level of comprehensive development. However, it declined significantly in 2015, and then began to grow slowly.

Comprehensive Evaluation

After getting the weight of each index through MATLAB, according to the formula $s_i = \sum_{j=1}^{m} w_j p_{ij}, i = 1, \dots, n$ each dimension is calculated separately. Through calculation, the comprehensive evaluation scores of each dimension of modern production system in Heilongjiang Province are shown in table 3-2 and Figure 3-1.

Table 3-2 comprehensive evaluation scores of various dimensions of modern industrial system in Heilongjiang Province

Years	Dimensions Regional competitiveness	Openness	Scientific and technological innovation	Educational culture	Ecological service
2005	0.0310	1.1398	5.4511	4.3827	0.0300
2006	0.8880	2.8422	6.3833	4.7364	0.5180
2007	2.0635	4.4979	4.4773	6.0020	1.2443
2008	3.6259	5.4949	4.8028	6.5247	5.4483
2009	3.9562	4.0217	7.2662	6.8008	5.2715

2010	6.1026	7.1304	8.0606	8.5497	7.2057
2011	9.0109	12.1194	10.1246	9.1056	8.1905
2012	10.6980	10.7480	11.5032	9.3539	9.3083
2013	11.9185	12.3245	7.2566	9.1215	10.4032
2014	12.6378	12.7014	9.7543	9.5867	11.6825
2015	12.5951	9.0072	9.3106	8.9675	12.4500
2016	12.8000	9.5058	8.0876	8.7956	13.4102
2017	13.6725	8.4670	7.5218	8.0728	14.8375

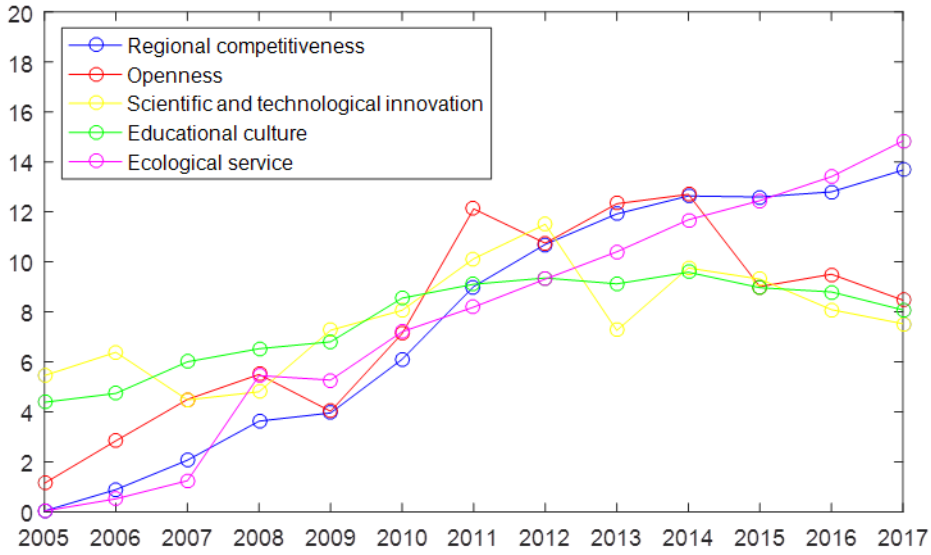

Figure 3-1 development trend of various dimensions of modern industrial system in Heilongjiang Province

It can be seen from table 3-2 and Figure 3-1 that the regional competitiveness and ecological service are the highest in 2017, which shows that the regional competitiveness and ecological service are increasing year by year, basically meeting the needs of the steady economic development of Heilongjiang Province, but the openness, scientific and technological innovation and education and culture are all in a slow decline trend after 2014, which is related to the unbalanced development of North and South in recent years and brain drain. At the same time, the development of regional competitiveness and ecological service in the modern industrial system of Heilongjiang Province is significantly higher than that of opening-up, scientific and technological innovation and educational culture, which shows that its development is unbalanced and inadequate.

Evaluation of modern industrial system in Heilongjiang Province Based on principal component analysis.

Establishment of principal component analysis model.

Principal component analysis (PCA) was first invented by Pearson in 1901. The main method is to decompose the covariance matrix (Abdi. H., & Williams, L.J. 2010) to reduce the dimension of the data while maintaining the maximum contribution of the data set to the variance (Pearson, 1901).

The comprehensive evaluation indexes of modern industrial system in Heilongjiang Province have different orders of magnitude. In order to avoid the impact on the results, the original data are standardized. Through principal component analysis of standardized data, three principal components are extracted from 23 indicators, and their eigenvalues, variance contribution rate and cumulative variance contribution rate are shown in table 3-3.

Table 3-3 eigenvalues of correlation coefficient matrix

principal component	**characteristic value**	**Variance contribution rate %**	**Cumulative variance contribution rate %**
F1	15.600	67.827	67.827
F2	4.176	18.157	85.983
F3	1.090	4.741	90.725

Table 3-3 shows that 23 indexes of modern industrial system in Heilongjiang Province can be transformed into three independent comprehensive indexes, with characteristic values of more than 1 and cumulative contribution rate of 90.725%, reducing the complexity of original data, achieving the purpose of dimension reduction, and reflecting most of the information of modern industrial system in Heilongjiang Province. The principal component indexes are comprehensive and independent, which avoids the overlapping interference between the original information and meets the analysis requirements. After the principal component load matrix is rotated, the load coefficient is closer to 1 or 0, so the principal component can better explain and name variables (Liyan, G. *et al.,* 2014). As shown in table 3-4.

Table 3-4 Component load matrix after rotation

Evaluating indicator	**Principal component PC1**	**Principal component PC2**	**Principal component PC3**
Total output value of primary industry	0.980	-0.078	0.017
Total output value of secondary industry	0.606	0.777	0.102
Regional total output value per capita	0.990	0.072	0.060
Added value of tertiary industry	0.977	-0.170	0.043
Total import and export of goods	0.421	0.830	0.074
Actual utilization of foreign capital	0.967	-0.195	-0.034
Loss making enterprises	0.139	-0.818	-0.040
Number of enterprises with R&D activities	-0.059	0.425	0.837
Proportion of internal expenditure of R&D funds in main business income	0.844	-0.078	0.320
Number of R&D projects	-0.038	0.860	0.135
Number of personnel in R&D organization of Enterprise Office	-0.523	-0.006	-0.706
Number of three patents authorized	0.898	0.100	0.104
All kinds of schools in the province	-0.989	0.021	-0.058
Number of teachers at all levels in the province	-0.340	0.864	0.067
Number of college students per 10000 people	0.867	0.313	0.161
Number of graduate from graduate school	0.961	0.097	0.127
Number of cultural relics and institutions	0.940	0.261	0.047
Number of cultural relics practitioners in the province	0.977	0.098	0.100
Having beds in health institutions per 10000 people	0.971	-0.209	0.040
Having health technical personnel per 10000 people	0.929	-0.122	0.108
Park green area per capita	0.921	0.300	0.095
Green food industry certification area	0.994	-0.010	0.038
Forest coverage	0.953	0.004	0.148

In the first main component of table 3-4, the total output value of the primary industry, the regional total output value per capita, the added value of the tertiary industry, the amount of foreign capital actually utilized, the proportion of the internal expenditure of R & D funds in the main business income, the number of three patent authorizations, the number of college students per 10000 people, the number of graduate students, the number of cultural relics institutions, the number of cultural relics practitioners in the province, the number of health institutions beds per 10000 people ten thousand people have health technical personnel, the per capita green area of the park have a large positive coefficient value, indicating that it increases with the increase of F1, and all kinds of schools in the province have a large negative coefficient value, indicating that it decreases with the increase of F1. F1 can be called the economic and people's livelihood indicators.

In the second main component, the total output value of the second industry, the total import and export of goods, the number of R&D projects, and the number of teachers at all levels in the province have a large positive coefficient value, indicating that it increases

with the increase of F2, and the number of loss making enterprises has a large negative coefficient value, indicating that it decreases with the increase of F2. F2 can be called the backbone development index.

In the third principal component, the number of enterprises with R&D activities has a large positive coefficient value, indicating that it increases with the increase of F3, the number of R&D institutions in enterprises has a large negative coefficient value, indicating that it decreases with the increase of F3, and F3 can be called the index of enterprises with R & D activities.

Table 3 5 ranking of main component scores, comprehensive scores and comprehensive development of modern industrial system in Heilongjiang Province

Years	F1	sort	F2	Sort	F3	Sort	F	Sort
2005	-1.52258	13	-0.72805	11	-1.23945	12	-1.34877	13
2006	-1.3651	12	-0.35384	8	-0.95821	11	-1.14145	12
2007	-1.205	11	-0.35643	9	1.12699	3	-0.91331	11
2008	-0.70867	10	-0.27568	7	0.42764	5	-0.56263	10
2009	-0.63447	9	-0.11651	6	1.14131	2	-0.43801	9
2010	-0.04638	8	0.78813	4	-0.71484	10	0.085701	8
2011	0.09289	7	1.66935	1	0.33271	6	0.420923	7
2012	0.26661	6	1.24795	2	1.72327	1	0.539128	6
2013	0.81275	5	0.89463	3	-1.46861	13	0.70992	2
2014	0.91098	4	0.69739	5	-0.58061	9	0.790288	1
2015	0.99094	3	-0.59206	10	-0.38054	8	0.602461	5
2016	1.14097	2	-0.99406	13	-0.14399	7	0.646534	3
2017	1.26704	1	-1.88082	12	0.73433	4	0.609214	4

It can be seen from table 3-5 that the comprehensive ranking of 2014, 2013, 2016, 2017 and 2015 ranked the first 5, 2007, 2006 and 2005 ranked the last 3, which is in line with the development of modern industrial system of Heilongjiang Province.

In 2007, 2006 and 2005, except for the F3 value in 2007, all other values ranked lower, which shows that the modern industrial system of Heilongjiang Province has made great progress compared with the original, and the overall trend is on the rise.

In 2014, F1 and F2 ranked ahead, while F3 ranked behind, which indicated that the economy, people's livelihood and backbone of Heilongjiang Province were relatively balanced in 2014, and R & D innovation capacity was still steadily improving. In 2017, F1 and F3 ranked ahead, and F2 ranked second to last, indicating that the modern industrial system of Heilongjiang Province has greatly improved in terms of economy, people's livelihood and innovation, but the development is extremely unbalanced, and the backbone of education, culture and foreign trade are weak, leading to the lack of overall development.

CONCLUSION

This study uses the improved entropy method and principal component analysis method to evaluate the modern industrial system of Heilongjiang Province in 2005-2017. The results show that the comprehensive score of the modern industrial system of Heilongjiang Province is the highest in 2014, and the development of the five dimensions of regional competitiveness, openness, technological innovation, education and culture, and ecological service is not only balanced but also efficient. In 2017, the development level of regional competitiveness and ecological service is the highest, but the other three dimensions are lower than that in 2014, the overall development is unbalanced, and the main forces in many fields are relatively weak. It shows that the economic, people's livelihood and ecological aspects of the modern industrial system in Heilongjiang Province tend to be gradually improved, but due to the unbalanced development between the north and the south, the cultural and educational are affected, leading to brain drain and lack of innovation.

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